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THE EFFECT OF SUBVOCAL SPEECH ON READING. FINAL REPORT.

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The development of reading ability and the nature of reading processes after the ability has been developed were investigated. A theoretical model of reading ability development was systematically tested by investigating the importance of muscular and auditory feedback in the initial stages, by investigating the relationship of vocalization and subvocalization to the difficulty level of reading material, and by evaluating an effective technique for the elimination of subvocalization in adults. Two experiments allowing specific testing of theoretical predictions were performed on college students. Following these, a study was undertaken on high school students. It was found that subvocalization was more prevalent when difficult materials were read and that it could be eliminated when nondemanding material was read. High school students did not respond to treatment as did college students, nor was the treatment as lasting. Non-reverters scored higher on IQ and reading tests and required fewer treatments. References are included. (JB)

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U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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July, 1968

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Curtis D. Hardyck

July 1968

The research reported herein was performed pursuant to a contract with the Office of Education, U. S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the Project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

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Summary

A. Objectives

To systematically test by experimental methods a theoretical model of the development of reading ability.

1. To investigate the importance of muscular (proprioceptive) and auditory feedback in the initial development of reading ability.

2. To investigate the relationship of vocalization and subvocalization to the difficulty level of reading material.

3. To evaluate an effective technique for the elimination of subvocalization in adults.

B. Procedures

Initially, two experiments allowing specific testing of theoretical predictions were performed on college students. Following these experiments, a study was undertaken on high school students, testing the applicability of the findings to students at less advanced levels of skill.

Introduction

Literally scores of volumes exist on the teaching of reading. Arguments for different methods of and approaches to teaching reading are similarly abundant. Research on these different methods and approaches has not been lacking, yet the problem remains one of concern.

Without presuming to judge the worth of existing research, it can be argued that previous work on the problem has primarily been oriented toward testing the efficacy of particular methods of teaching. Theories of reading development also frequently tend to reflect biases toward particular teaching methods (see D. H. Russell, 7; H. Diak, 3).

The present project concerns the investigation of the development of the ability to read and with the nature of the processes after the ability has been developed. Emphasis is placed on the testing of a learning model incorporating both physiological and cognitive components. The studies differ from many other investigations in that the experiments are concerned with the problem of learning to process and encode information apart from any given teaching model. Emphasis is placed on the physiological components of the motor skills hypothesized as the basis of the initial learning process and on their transition into neural and cognitive processes.

A. Theoretical Model

The theoretical model developed for this work is basically an extension of Osgood's mediational hypothesis (Osgood, 6), utilizing additional constructs to explain the development of the ability to read. Osgood, in his development of a system to account for the attachment of meaning to verbal responses, has provided the outline of a conceptual framework. Initially, he proposed that the child develops a "circular reflex." This reflex is developed during the stage of development in which the child emits spontaneous noises. During this stage, syllable units which the infant "babbles" become integrated and the child becomes able to repeat his own vocalizations using auditory feedback. Gradually, as the child acquires greater muscular control, he forms some initial associations between events occurring around him and certain sounds, and he attempts to imitate them. In this stage, the child imitates the sounds others produce. This involves a primary generalization from self-produced auditory-proprioceptive cues to auditory cues produced by others. The child is rewarded for this both by having his needs attended to more promptly when he can specify them and also by receiving praise and attention from the parents. In the final stages of labelling and semantic encoding, the sight of the object evokes an auditory-proprioceptive mediation process (r_m'--s_m') and an associated imitative labelling. In addition there is a secondary association between the mediation process and the imitative process. When this occurs, Osgood believes that the unit of linguistic encoding has been established, since the two staged mediated association between sight of the object and imitative labelling is a representational process free of the physical presence of the object itself.

The development of the mediational series is thought by Osgood to occur as follows: The ability to visually discriminate objects such as a ball is postulated as a fundamental attribute of the organism. For the child, this perception will, over time, become associated with a certain stimulus complex: the size, color, etc. of the object and also the memory of the pleasant autonomic reactions associated with playing with the ball. Osgood characterizes this process as follows:

> " . . . according to the mediation hypothesis, the sight of this ball as a visual sensory integration, initially meaningless, will come to elicit some distinctive portion of the total behavior to the object as a representational mediation process (r_m'--s_m'). To the extent that this process occurs, the visual pattern becomes a perceptual sign (S) signifying BALL object, e.g., this is a unit in perceptual decoding." (Osgood, 6, p. 93)

This representational mediator becomes linked to a stimulus complex which includes the pleasant autonomic reactions to playing with a ball, the sound "ball" and the child's own efforts to imitate this sound. As the child's efforts to emit this sound improve, he is

usually rewarded (primarily by praise from the parents), and, consequently, stimulated to practice the emitted sounds.

To briefly recapitulate, it has been hypothesized that certain motor and auditory stimuli become associated with certain perceptual phenomena. As sensory integration develops, these complexes of stimuli become representational mediation processes.

In this way, it is hypothesized that the child acquires a system of expectancies that certain actions on his part have certain sensory consequences. This primitive set of associations forms the basis for later verbal learning. The next stage in development is the association of verbal responses to objects in the environment. The first stages of learning are assumed to be imitative, the child attempting to emit the same sound as the parent and being rewarded for his efforts. In this manner, a large number of auditory-proprioceptive (a-p) responses are established to visual stimulus objects. The response "ball" is at first applied to balls of all sizes and colors and even to any object that even roughly approximates the perceptual characteristics of a ball. Thus, a large set of stimulus objects evoke the same generalized response.

The next stage of development is characterized by the formation of discriminations and the development of subcategories of response to various stimulus objects, again by the action of imitation and the application of selective rewards and punishments.

Once the basic modes of approach have been developed, the process proceeds quite rapidly. By the age of 3, the child has a large number of a-p and stimulus object relations well established. In Osgood's terms, a large amount of perceptual decoding has occurred and been stored--and this storage is based primarily on the sensory components of the a-p response.

Osgood has characterized the formation of skills as occurring in three stages:

> " . . . (1) A very slow and uncertain pattern for ordering of responses on the basis of exteroceptive controls, as in imitating the seen movements of another person; this makes possible (2) a transfer gradually to proprioceptive controls (feedback), accompanied by considerably increased speed of execution; and this more rapid stable orgnization in turn makes possible (3) a transfer to central programming in the integrational motor system . . . " (6, p. 84).

It is at this point that an elaboration of Osgood's model becomes necessary. Osgood has concerned himself with the analysis of meaning, and his conceptual model outlines the initial stages of development and the later process of the interpretation of meaning, omitting the problem of decoding experience in modes other than the direct perception of objects.

In terms of stages of integration, it can be hypothesized that decoding the environment by means of a speaking vocabulary has already reached stage three; it is centrally programmed. For example, one source (Diak, 3, p. 12) states that a pre-literate 4 year old child will have a speaking vocabulary of approximately 1500-2000 words used correctly. In other words, the child not only has a centrally programmed vocabulary, he has also learned the grammatical rules for its usage (cf. Church, 2).

At this point, the child is asked to learn a completely new method of decoding the environment. He is quite comfortable in the knowledge that the sound "ball" stands for a class of objects having certain perceptual qualities (roundness, resilliency, etc.) and certain types of meaning (playthings), that the sound "kitty" stands for a certain class of animate furry objects having certain qualities, and so forth. Now he is asked to learn that a set of symbols (offering many fewer cues in terms of perceptual richness) can also stand for these objects.

The process of learning to read can be conceptualized as a motor skill developing through several stages of integration into a centrally programmed neural analogue. In this model, the preliminary development of reading skill corresponds to Osgood's second stage of skill formation. The preliminary stages of learning to read are characterized by the production of (1) sounds that are the speech responses to visual stimulus objects and (2) the proprioceptive and auditory consequences of producing these sounds which serve as stimulus support for other responses. This stage characterizes the programmed meaningful speaking vocabulary of the child. The end of this stage is reached when the associative linkages between the perception of the object, pictures of the object, the auditory-proprioceptive stimulus complex, and symbols of the object (written words) are all established.

A necessary assumption here is that the mediational process of association to a new set of visual stimuli (letters in the form of words) is essentially the same process as that occurring between object perceptions and the auditory-proprioceptive stimulus complexes. The child again finds that the a-p stimulus complex is a more stable and invariant stimulus component than is the visual stimulus (the printed word appears in a variety of forms and may be applied to a variety of pictures and objects) while the stimulus consequences of his saying the word are less variant. Consequently, the initial stages of reading are also characterized by the formation of visual symbol (letters and words) and a-p associations. In addition to these structural environmental bases for the a-p associations assuming a major role in reading development, the prior experiences of the child also predispose him to develop this mode of response. In the past, when the child has been faced with the problem of associating arbitrary sets of symbols, the most stable mediator was the a-p complex.

Therefore the child would be expected to adopt the same field-cognition-mode (in Tolman's terminology) which proved satisfactory in the past.

It is postulated that as these linkages become established, less and less redundancy such as is provided by the auditory-proprioceptive stimulus complex is needed. Consequently, components of the stimulus complex are gradually eliminated. The auditory component is eliminated first, gradually lowering the level to inaudibility. The proprioceptive component also diminishes in intensity but at a slower rate than the auditory component. These components probably are eliminated since, at later stages of reading development, speed is demanded of the response, and these motor and proprioceptive components are slow speed reactions. They must then be eliminated if fast reading rates are to be attained. Also, a qualitatively more flexible and less stimulus bound mode of response is now urged on the reader.

As the linkages between symbols and perceptions are strengthened, the auditory component disappears completely, or remains only as a neural analogue. The proprioceptive component remains as a source of stimuli after the auditory component has dropped out.

As facility is gained in the symbol-perceptual linkages, the stimulus support provided by proprioceptive sensations becomes less important and diminishes in intensity. As the responses continue to become further integrated, the proprioceptive stimuli, being slow, are gradually eliminated as a source of stimulus support.

At this stage, we postulate the development of a neural analogue of the original motor (auditory-proprioceptive) process. We assume that the integration of the neural analogue parallels the motor integration process. As the final stages of integration are reached, the individual develops the ability to read entirely on the basis of a set of symbols with additional stimulus support becoming unnecessary under ordinary circumstances.

Perhaps a comment about the adequacy of the theoretical model is appropriate at this time. Many linguists have been critical of the adequacy of psychological learning models such as the present one to account for both (1) the tremendous variety of verbal utterances and (2) the generation of completely new verbal statements (cf. Chomsky, 1). Linguists argue that, in addition to the denotative aspects of language, one also learns a grammar and syntax such that unique statements which will conform to existing language rules are possible. However, many of the linguists espousing this criticism also conclude that psychological learning models, since they do not account for the complexity of language are therefore invalid, even for a simpler level of explanation. This seems an unwarranted conclusion. A theoretical model admittedly may be inadequate to account for the full complexity of a set of events but be quite adequate for the level of explanation attempted. We would agree that there are undoubtedly centrally programmed rules of grammar and syntax which exert significant control over the formulation and generation of verbal statements, but

would not agree that this violates our conception of how denotative language develops. The conception presented here can be considered as essentially learning to substitute one set of symbols (printed forms) for an already established set of symbols (the a-p stimulus complex associated with the words themselves). This presupposes the existence of centrally programmed rules of grammar and syntax and presents no difficulty for our conception, which is basically a symbol substitution model.

It would, of course, be of great interest to study the ways in which such "central programs" are acquired, developed, and utilized, but that is beyond the scope of the present study.

B. Review of Previous Work Stemming from the Theoretical Model

The problem of subvocalization, or whispering to onself while reading, has received a good deal of attention and comment on the anecdotal level, but relatively little systematic study, with the exception of the work by Edfeldt (4). The problem is one of the most difficult stumbling blocks to overcome in increasing reading speed. An individual who subvocalizes to any great extent (the term subvocalization is used here to include a wide range of activity, from inaudible articulations and vocalizations to audible whispering while reading) is limited to a top reading speed of approximately 150 words per minute--a maximum speed attainable while reading aloud. If the response is visible, as in movements of the lips and jaw, some corrective measures are possible. However, if the activity is limited to the vocal musculature, the problem of eliminating this response becomes much more complex, especially since individuals are often not aware of these behavior patterns and have difficulty focusing on them.

Initial work in the study of subvocalization began with the examination of several subjects with strong subvocalization patterns to determine whether electromyograms recorded from the throat could detect subvocalization while reading. It was found that subvocalization could be successfully detected by means of surface electromyography, using electrodes placed onthe throat opposite the vocal muscles. The procedure for recording the electromyogram was as follows. First, the skin of the throat was rubbed very lightly with extremely fine grade sandpaper. Next, the sandpapered area was scrubbed with an anti-bacterial skin cleanser and dried with a towel. Bipolar electrodes of pure silver, one centimeter in diameter, were then taped to the skin surface. The electrodes were in the shape of a half-sphere with a flat rim surrounding the sphere. The half-spherical hollow contained electrode paste. Skin resistance was kept at or below 5,000 ohms. A type R Offner ink-writing oscillograph was used to record the electromyogram. It was found that use of the maximum sensitivity of the unit permitted

detection of the electrical activity of the vocal muscles while the subject was reading, (if subvocalization was present) in contrast to a minimal signal (approximately 3 microvolts) obtained when the subject was relaxed, and an extremely strong signal (approximately 1 millivolt) obtained when the subject spoke at normal conversational level. The normal procedure in determining the presence or absence of subvocalization was to provide the subject with light fictional reading material chosen by the subject himself. The subject then was allowed to read undisturbed for a period of 30 minutes during which time the oscillograph record was monitored and swallows and head movements were noted by observation of the subject in conjunction with the oscillograph record.

Determination of subvocalization was checked in a number of ways; the subject was asked to stop reading while maintaining the same position, then begin reading and then stop reading. Each time the changes in the electromyographic record were noted. Under these circumstances, the presence of subvocalization was detected quite reliably, there being an easily visible increase in action potentials the munite reading began and an immediate cessation of this activity the munite reading stopped.

Treatment of subvocalization was done in the following manner. The subject was asked if he was aware that he subvocalized or read aloud to himself. A brief discussion was held with the subject, informing him of his response tendencies while reading. The feedback technique was then introduced. The subject was told that he would be able to hear the activity of his vocal muscles as he read and that this would help him eliminate the problem. The manner in which signals emanating from the subject's vocal muscles were detected was explained to him. The subject was then given earphones to wear and was asked to remain relaxed. When the oscillograph record indicated that the subject was quite relaxed the feedback was introduced. The feedback was introduced by channeling the output of the Offner oscillograph amplifier to an audio amplifier and then to earphones. The subject was asked to relax so that a sudden burst of sound would not prove startling. When the feedback was opened to the subject he was then asked to swallow. The swallow immediately produced a burst of static in the earphones. The subject was then requested to experiment with the sound to satisfy himself that he could control it, stop it, and start it, by such actions as talking, swallowing, truning his head, clenching his jaw muscles and so forth. The subject was allowed to continue experimenting with the feedback and with its control until he stated that he felt quite comfortable about being able to control its presence or absence. The subject then began reading under the feedback condition. At this time, the experimenter donned earphones to monitor the signal experienced by the subject. If the subject encountered difficulty, the experimenter would halt the feedback briefly and ask the subject what sort of problems he was having. The subject continued to read while attempting to keep the

electromyographic feedback to an absolute minimum, in other words, to maintain silence in the earphones. The electromyogram sounds like low frequency static, having a modal frequency of approximately 80 to 90 cycles per second. The low frequency of the EMG is due to the integration of the signal over a one-fifth second time constant thus eliminating the extremely high frequency notes. Occasionally, if the subject began to adapt to a given level of noise the experimenter, who continued to monitor the feedback given to the subject, would increase the gain, thus forcing the subject to pay attention. Occasionally, a reminder to the subject was necessary.

A pilot study was done using students enrolled in a reading improvement course at San Francisco State College. All students enrolled in the course had an initial diagnostic electromyogram to determine whether subvocalization was present.

A total of 35 subjects were tested, of whom 7 were found to subvocalize. All subjects who were found to subvocalize were treated in the manner described. Originally, it had been planned to administer the feedback treatment over several sessions to attempt to determine how many feedback treatments were necessary to establish normal non-subvocalizing reading habits.

This was found to be unnecessary--the feedback treatment was found to be remarkably effective. In the majority of cases one session of the feedback was sufficient to result in the complete cessation of subvocalization. Repeated tests over several months time have indicated no change from the effectiveness of the initial feedback session once control has been learned. In many ways, this is quite a puzzling phenomenon. One does not expect the extinction of a habit which probably has existed during the entire time the subject has been reading to occur so quickly and so easily. One hypothesis has been formulated to explain this one-trial phenomenon. The introspective reports of the subjects who have undergone this treatment indicated that one of the problems they faced in learning to control the feedback was in learning to breathe normally without becoming tense because of their concern over their subvocal activity. Once they were able to breathe in a normal regular fashion, the control of the feedback became much easier. this suggests that the breathing rate present in subjects who subvocalize may be identical to that present during audible speech. In other words, the subject exhibits exactly the breathing pattern that he would if he were reading aloud at normal conversational or speech level. Disruption of the subvocalization pattern therefore may disrupt this irregular breathing pattern and replace it by a normal and regular breathing pattern. This replacement of an abnormal physiological pattern by a normal response would explain the ease with which subvocalization is treated by this method. However, a test of this hypothesis remains to be done.

Originally, in the pilot study done at San Francisco State College, it was planned to set up multiple groups and compare subjects who were recorded several times but did not receive feedback. The limited number of subvocalization subjects prevented this from being done. In addition, because of a number of questions concerning the appropriacy of the teaching methods in the course and the adequacy of the measures used to determine reading speed and comprehension, a detailed and complete study was not feasible. However, the preliminary study was valuable in that (1) it demonstrated the remarkable effectiveness of the continuous feedback technique in treating this problem, (2) it clarified problems of technique and procedures that will facilitate a systematic and comprehensive study of this phenomenon.

Methods

A. Experiments

The following section presents, in detail two experiments which serve to test the primary propositions of the theoretical model.

1. The Relationship of Difficulty Level of Material to Subvocalization.

The conceptual model postulates that vocalization and subvocalization are important constant sources of stimulus support during the early stages of learning to read. As skill increases, the vocal stimulus sources are gradually eliminated and are replaced by neural analogues of this process. Since vocalization and subvocalization are postulated to be primary sources of stimulus support during the initial stages of reading development, it is quite possible that this support is again utilized when someone who can read normally with no tendency toward subvocalization is faced with extremely difficult material. Some earlier work by Edfeldt (4) tends to support this hypothesis.

These predictions can be elaborated as follows: .

1. Individuals who normally read without subvocalization will revert to subvocalization when faced with reading extremely difficult material. (The difficulty of the material is defined by expert judges' ratings of difficulty of comprehension.)

2. If subvocalization during the reading of difficult material is prevented by use of the continuous feedback technique, reading time will increase and comprehension will drop, due to the loss of stimulus support.

3. The changes in reading time and comprehension under conditions of feedback will be significantly greater (longer reading time and lower comprehension) than under conditions of distraction such as non-response contingent feedback. This condition establishes that the feedback condition is not merely a distraction to learning.

The following experiment was done to test these predictions. College students were subjects for this study. Criteria for selection were (1) absence of subvocalization as established by electromyography, (2) a "normal" reading rate for college students.

The material the subjects were asked to read was scaled in terms of high medium and low difficulty, with interest held as

constant as possible. The material was selected by having judges (instructors in basic English courses at the University) read the selections and then rate each of them on a five point scale for both difficulty level and for interest level. From this pool of selections, three were selected which varied widely in rated difficulty but which were rated similarly in interest level. The easy selection is a brief biography of J. F. Kennedy, covering the period from his announcement of his candidacy for the presidency to his assasination. The medium selection is an article by Oscar Handlin on the "Culture of Cities" originally published in Daedalus. The hard selection is a chapter from Norbert Weiner's popular book "The Human Use of Human Beings" on the concepts of entropy. Subjects were initially selected from the basic English classes at the University and participated in a pre-test run to become familiar with the conditions of the study and with the apparatus. Following the pretest each subject participated in three experimental sessions.

I. The Normal Condition:

In this condition the subjects read the easy, medium, and hard selections (these selections were counterbalanced over subjects to counteract for the effects of order). Laryngeal electromyograms (EMG), chin-lip EMG, trapezius EMG, eye-movement and respiration were recorded before, during, and after reading.

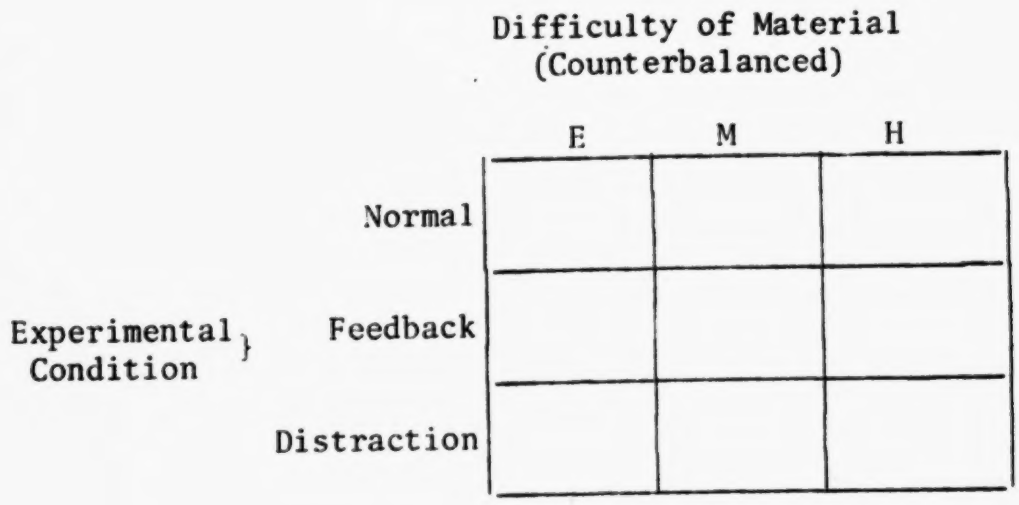
II. Feedback Condition:

Conditions were the same as for the normative condition except that laryngeal activity was fed back to the subject. A Schmidt Trigger-relay driver system was used to trigger a 500 cycle tone through a loud speaker to the subject every time laryngeal EMG rose above the normal relaxation level determined at the beginning of the session. Subjects were instructed to keep the tone off as much as possible while reading the selections.

III. Distraction Condition:

Everything was the same as for the other two conditions except that a 500 cycle tone was sounded intermittenly during the time the subject was reading. This tone was tape recorded while a feedback subject read each of the three selections. The intent was to simulate the distraction caused by the tone for all feedback subjects by presenting the feedback tone as often but making it non-contingent on laryngeal EMG activity.

Following the preliminary testing mentioned earlier, three sessions were scheduled at one week intervals.



N = Normal Condition
F = Feedback Condition
D = Distraction Condition

E = Easy Selection
M = Medium Selection
H = Difficult Selection

After the electrodes were attached for laryngeal, chin-lip and trapezius EMG, the subjects were asked to relax for a brief period of time during which a resting level baseline was established. The subjects were then told to begin reading. When they finished the selection, another relaxation baseline was taken. The electrodes were then removed and the subject was given a short multiple choice examination on the material just read.

The theoretical model assumes that auditory-proprioceptive (A-P) stimuli are the most stable sources of stimulus support during the preliminary stages of learning to read--when the perception of words is dependent on A-P feedback at the vocal and later at the subvocal level to mediate the meaning conveyed by the word symbols. All studies of skill formation indicate that with highly developed skills, when difficulty is encountered, the subjects will adapt modes of response which previously were successful. Consequently, as the subject is faced with reading material of increasing difficulty, we predict that subvocalization will increase as more and more stimulus support is sought in order to master the task. The following predictions were made for the variables studied, in relation to the increase in difficulty for the reading material.

1. For laryngeal and chin-lip EMG D>N>F. The feedback condition will by definition have the least amplitude. The prediction is that subvocalization will be most pronounced during the distraction condition.

2. Trapezius EMG N=D=F. No differences are expected among the control electromyograms.

3. Comprehension N>D>F. This prediction is based on the premise that the normal condition has the least interference and the greatest

stimulus support. The distraction condition has stimulus support equal to the normal condition but the distraction is assumed to have some hindering effects. The feedback group, having less redundancy of information due to blocking of the auditory-proprioceptive stimulus complex, should have the lowest comprehension scores.

The electromyographic data was converted to digital form by means of an IBM 1800/360 analog to digital conversion processing system. The converted electromyographic data was analyzed in a three-factor repeated measurements design allowing for a contrast in experimental condition, difficulty level and muscular group. Outcome values are expressed in terms of microvolt-seconds averaged within an experimental period. Significant F values were found for experimental conditions ($F_{2,15} = 7.21$), muscle group ($F_{2,30} = 7.57$) interaction between experimental conditions and difficulty of material ($F_{4,30} = 5.67$), and interaction between experimental condition and muscle group ($F_{4,30} = 5.75$). No other F values exceeded 1.00. Figure 1 depicts the interactions between experimental conditions and difficulty level and indicates clearly that a striking drop in level of laryngeal muscle activity occurs under the feedback condition while a strong rise in laryngeal activity is present under normal and distraction conditions. Figure 2 depicts the relationship between muscle groups and experimental condition, again indicating the drastic change found in laryngeal muscle activity under feedback conditions: The chin-lip EMG shows the same pattern of activity as does the laryngeal EMG but the change is much less extreme. The control (trapezius) EMG remains essentially unchanged across conditions. The results are extremely close to the predictions made for changes in muscle activity under feedback and distraction conditions. The lack of change in the level of activity of the trapezius clearly indicates that changes are specific to the task and do not represent simply a generalized increase or decrease in muscle tension.

When the comprehension data are analyzed the results are not as striking. The direction of change for comprehension is as predicted: Retention is less under feedback than under distraction. However, the results do not reach statistical significance. Our comprehension measure has been revised and greatly improved and a repetition of the experiment is planned using these revised comprehension measures. However, even without this planned replication the basic predictions stemming from the theory have been confirmed. This study does provide evidence that subvocalization acts as an additional channel of stimulus input in reading.

2. Continuous Feedback Techniques applied to the Problem of Subvocalization: A Replication.

This experiment is a replication, with additional controls, of the pilot study discussed in the account of previous work.

Figure 1

Interaction of experimental condition with difficulty level on laryngeal EMG

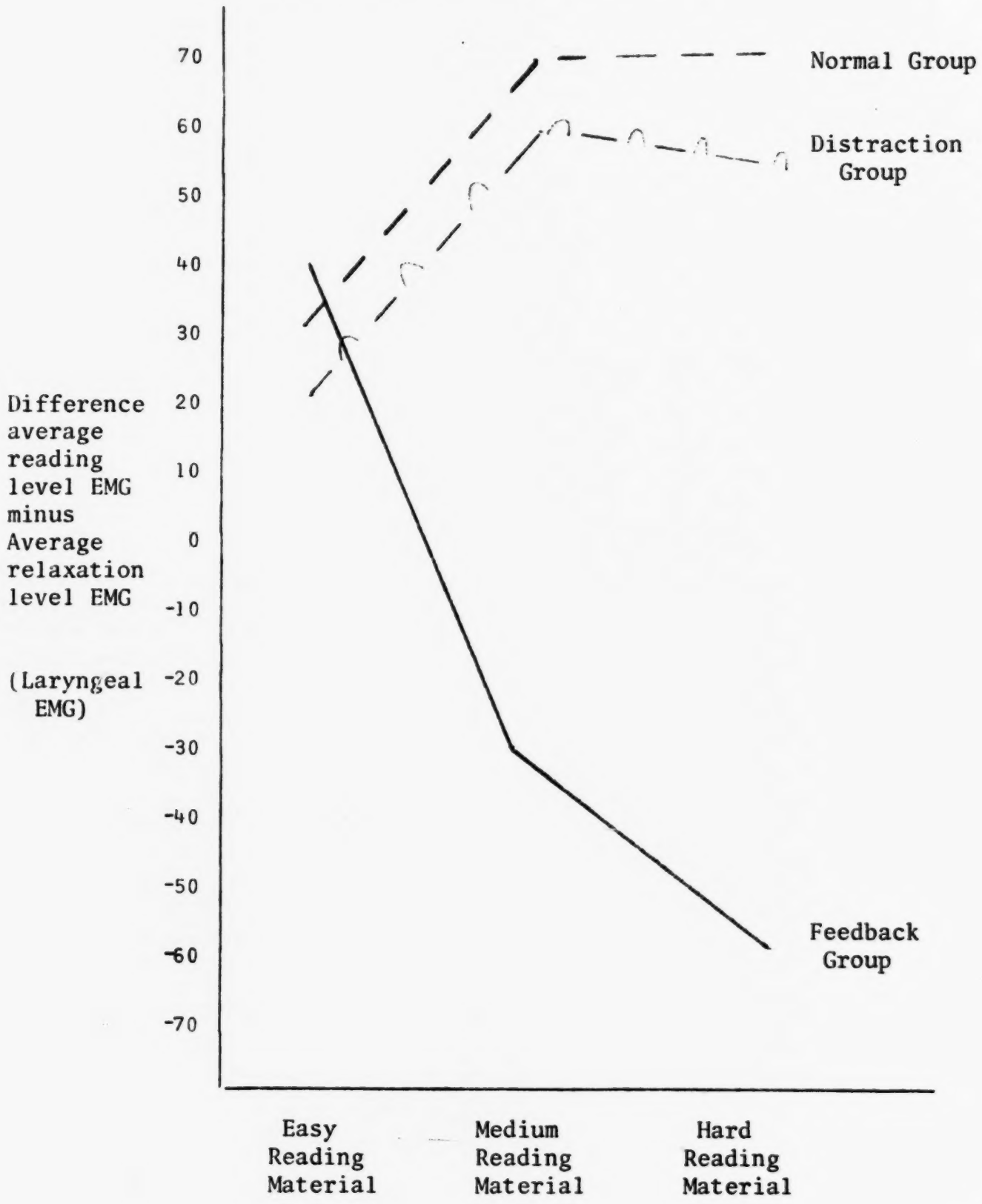
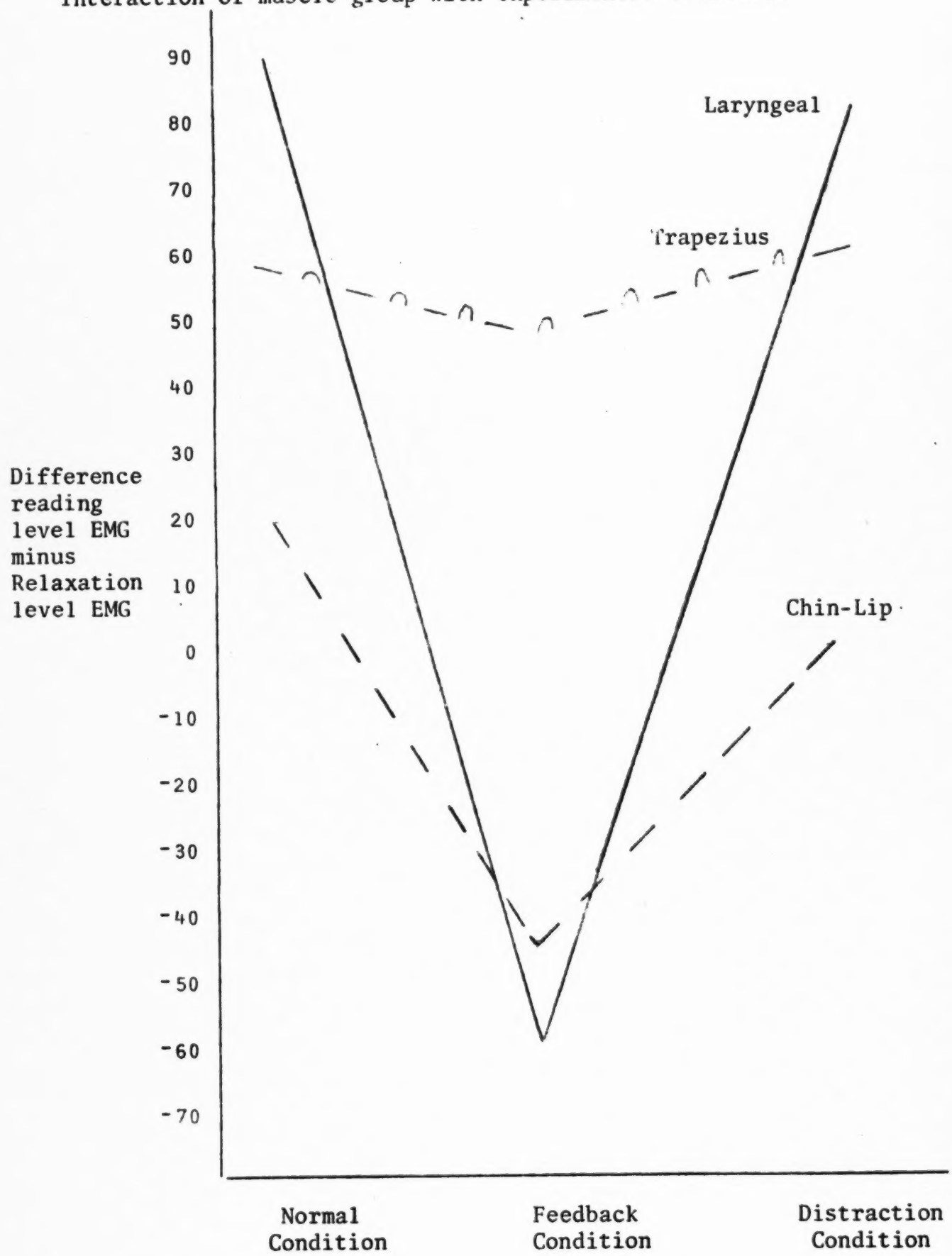


Figure 2


Interaction of muscle group with experimental condition
Difference reading level EMG minus Relaxation level EMG
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Laryngeal
Trapezius
Chin-Lip
Normal Condition
Feedback Condition
Distraction Condition

The conceptual model leads to the prediction that subvocalization represents a proprioceptive feedback stage of integration of reading skill, preliminary to the final development of a neural analogue of the original set of motor skills. The presence of subvocalization in an educated adult such as a college student indicates that the elimination of an earlier stage of skill formation is not complete. Consequently, we would predict that individuals who were trained to eliminate subvocalization by the continuous feedback technique discussed in the work presented earlier should respond much more rapidly to measures designed to increase reading speed than would corresponding control groups.

The pilot study indicated that this technique applied to the problem of subvocalization was feasible and quite efficient. The replication study is described below.

First, it was necessary to identify a group of individuals who subvocalize while reading. The only way in which this could be definitely established was to take electromyographic readings from a University population, selecting those who do subvocalize. Two such groups of subjects were selected. They are defined as follows: (1) Experimental group: this group was composed of 32 subjects and received the continuous feedback treatment. (2) Control group: a group of 30 subjects identical in all ways possible with the Experimental group. This group served as the electromyographic control subjects identical in all ways possible with the Experimental group. This group served as the electromyographic control group for the Experimental group. They received the same number of electromyographic sessions, but were simply recorded and did not receive the feedback treatment until after this experiment was concluded.

Once the groups were randomly selected the following measures were taken:

1. The electromyogram from the throat while reading and while relaxed.

2. The measurement of breathing pattern.

Once initial levels for the individuals in the Experimental and Control groups were reliably established the Experimental group was exposed to the feedback system to eliminate subvocalization.

B. Treatment Results

Approximately 200 subjects were screened for subvocalization during the one year of this project. Out of those subjects who subvocalized, 32 were placed in a treatment group and 30 in a control group. The results indicate that all subjects treated

responded within the usual short period of time (less than one hour) and did not revert to subvocalization. Repeated screenings over several months indicate that subvocalization did not recur. Control subjects seen for several sessions showed reliably stable subvocalization patterns.

Examination of pre and post-treatment reading speed scores indicated that little change occurred in speed after removal of subvocalization. Current data indicate that those subjects who were treated are able to benefit from speed-reading training more than those who have not been treated for subvocalization. However, the small numbers of subjects do not permit precise conclusions.

In addition to the college treatment series, one hundred and twenty students in grades seven through twelve enrolled in Emery High School, Emeryville, California, voluntered and participated as subjects. Emery High School is mostly composed of Negro, working class students. Tests given the 10th graders showed that 75% of them had an I.Q. of less than 100 and 60% were in the 4th quartile of national scores on academic achievement tests, these scores are probably representative of the entire school.

Procedure

Surface EMG's were recorded from the laryngeal muscles and the trapezius muscle, and respiration was measured by means of a strain gage chest band. These were recorded on a Beckman-Offner Type R dynograph. Each subject chose his own reading material from a variety of books judged by Scholastic Books, our staff, and the Emery High reading instructor to be one year below his reading ability as indicated by reading tests. The subject read one or two paragraphs aloud to make sure he could read with relative ease. He was then asked to read silently for three 5 to 10 minute periods with a short rest period between each. Head and body position were controlled. After each session the subject was asked to summarize what he had read. If he could not, the session was considered invalid since the subject may not have been reading. Those subjects showing an increase in laryngeal EMG without a corresponding increase in trapezius EMG (gross body tension) during the first, diagnostic, session were classified as subvocalizers and given one of three forms of the Gates Reading Survey and treated for subvocalization as described in Hardyck, Petrinovich, and Ellsworth (5) with one refinement. Instead of the loudness of auditory feedback varying with amplitude of EMG, an audio-oscillator and Schmitt Trigger produced a steady tone when the EMG amplitude exceeded the normal resting level. The subjects were instructed to read and keep the tone off as much as possible.

The one-half hour treatment sessions were each preceeded by a short diagnostic session and were repeated once a week until the

diagnostic session indicated that the subject did not subvocalize. Then a second form of the Gates Reading Survey was given.

One month afterward each subject was given another diagnostic session and was retested on a third form of the Gates Reading Survey. The Gates Reading Survey is composed of speed and accuracy, vocabulary, and comprehension tests, reported in age and grade reading levels.

Results

Of the 120 volunteers 30 were found to be subvocalizers and of these 30 only 13 received the treatment and the month retest. The other 17 were rejected from the experiment because of excessive movement, refused to participate, or such a low reading level (below the 5th grade level) that reading tests were not valid. One case was eliminated because there was no response to the treatment after five sessions. It should be noted that the ratio of subvocalizers to nonsubvocalizers is approximately the same as for poor reading college students.

The 13 subvocalizers required from one to three treatment sessions with a mean of 1.9 sessions before the subvocalization was eliminated. This is markedly different from the college students who inevitably responded to the first treatment. It is doubtful that this difference is due to either a shorter attention span or to the shorter treatment sessions. The college students responded within the first few minutes of the treatment session and the high school students did not. In some cases the high school students apparently responded to the first treatment but diagnostic sessions one week later showed that they reverted to subvocalizing.

On the one month-retest eight of the thirteen subjects reverted to subvocalizing, whereas none of the college student subjects reverted. The average of all Gates scales rose seven months in reading level between the first and last testings. While some of this rise is undoubtedly due to the passage of time, the total change is too extensive to be accounted for on this basis alone. The added attention given the subjects who volunteered for the study may account for this difference, but additional treatment and control subjects would be needed to determine this.

The eight subjects that reverted to subvocalizing did not differ in age from the five that did not. The average ages of both reverters and non-reverters was 15.1 and there was no difference in school grade between the two groups. They did differ in the number of treatment sessions required to eliminate subvocalization, in I.Q. scores, and in reading test scores. The reverters required a mean of 2.1 treatment sessions to extinguish subvocalization while the non-reverters required only 1.6 sessions. The mean I.Q. of

of reverters was 94.3 ranging from 80.00 to 115.00, that of non-reverters was 112.8 ranging from 93.00 to 148.00. The reverters did more poorly on the Gates Reading Survey.

Summary

Working class high school students did not respond as quickly to a feedback treatment for eliminating subvocalization during silent reading as did college students nor was the treatment as lasting: eight out of thirteen subjects reverted within one month. The non-reverters scored higher than did the reverters on I.Q. and on reading tests, and they required fewer treatment sessions.

C. Conclusions

The conclusions of these studies can be made briefly and succinctly. Evidence presented in the two experimental studies indicate, without any doubt, that subvocalization is (1) an involuntary stimulus input utilized by all individual as the difficulty level of the information to be processed increases. (2) Subvocalization can easily be eliminated when it is not necessary such as when reading relatively nondemanding material. This can be done with no attendant loss in comprehension.

These studies indicate the importance and the generality of the phenomenon. However, a number of questions remain to be answered. While the majority of our low ability subjects seem to subvocalize automatically, it remains to be seen that this process is used by all subjects when facing what is for them difficult information to be processed. It may well be that with some subjects it would pay to reverse our procedure and to encourage them to subvocalize and to perhaps actually vocalize as a way of increasing the richness of information input. Similarly, our results suggest that those subjects of average and above average ability who continue to subvocalize long after the need for such high redundancy in information input has passed, are in a position analogous to that of a sprinter forced to wear lead weights in his shoes. The benefits of feedback treatment for these subjects, both in terms of relief of physiological fatique and in increased reading speed were evident within a relatively brief period following the treatment. If further research supports these conclusions it might be appropriate to institute the general program of screening and treatment in high schools and in the first two years of college to detect those students of average or above average ability who have not eliminated subvocal activity and to treat them as quickly as possible.

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800 ABSTRACT
801 Literally scores of volumes exist on the teaching of reading. Arguments fo
802 different methods of and approaches to teaching reading are similarly abundant.
803 Research on these different methods and approaches has not been lacking, yet the
804 problem remains one of concern.
805 Without presuming to judge the worth of existing research, it can be argued
806 that previous work on the problem has primarily been oriented toward testing the
807 efficacy of particular methods of teaching. Theories of reading development also
808 frequently tend to reflect biases toward particular teaching methods.
809 The present project concerns the investigation of the development of the
810 ability to read and with the nature of the processes after the ability has been
811 developed. Emphasis is placed on the testing of a learning model incorporating b
812 physiological and cognitive components. The studies differ from many other inve
813 gations in that the experiments are concerned with the problem of learning to
814 process and encode information apart from any given teaching model. Emphasis is
815 placed on the physiological components of the motor skills hypothesized as the
816 basis of the initial learning process and on their transition into neural and
817 cognitive processes.
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